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such as vinyl ethylene carbonate, vinyl quinone, vinylcrotonate and derivatives thereof, 9-fluorenone, vinyl acetate, vinylimidazole tribally triazine trione, 4,5-diethenyl-1,3-dioxolan-2-one, 4-ethenyl benzene-1,3-dioxolan-2-one, methyl silyl carbonate, 1,5-hexene-2,3-carbonate, 4-methyl-4-silyl-1,3-dioxolan-2-one, 4,5-diphenyl- 1,3-dioxolan-2-one, 4,4-diphenyl-1,3-dioxolan-2-one, vinyl ethylene sulfite, 4-methoxymethyl-1,3-dioxolan-2-one, 4-hydroxymethyl-1,3-dioxolan-2-one, 4-(1-propenoxymethyl)-1,3-dioxolan-2-one, 4-(2-propenyl)-1,3-dioxolan-2-one, ethyl-2-furoate, 4-ethenol-1,3-dioxolan-2-one, 2-methoxyl-1,3-dioxolan, monofluoro ethylene may be used to passivate the anode or negative electrode and also prevent gassing, extend the calendar and cycle life of the battery and assist in improving the safety of the battery or cell. These later named additives also have the added property of preventing exfoliation of graphite containing anodes in the presence of propylene carbonate.

Accordingly, it is a primary objective of the invention to address the aforementioned need in the art by providing a lithium battery containing flame retardant material and/or anode passivating material in the non-aqueous electrolyte. The invention consists of certain novel features and a combination of parts hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the details may be made without departing from the spirit, or sacrificing any of the advantages of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawings a preferred embodiment thereof, from an inspection of which, when considered in connection with the following description, the invention, its construction and operation, and many of its advantages should be readily understood and appreciated.

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FIGURE 1 is a graphical representation showing the relationship between the discharged capacity of the battery and the number of battery cycles with 5 weight percent vinyl ethylene carbonate (curve A), 5 weight percent triphenylphosphate (curve B) and a mixture of vinyl ethylene carbonate, triphenylphosphate and monophenyl-dibutyl phosphate (curve C) as flame retardants;

FIGURES 2(a)-2(c) are self-heat rate curves from ARC experiments with various additives with Figure 2(a) showing data for a 5 weight percent VEC in the electrolyte and Figure 2(b) showing data for electrolyte with 5 weight percent TPP and Fig. 2(c) shows data for electrolyte with a mixture of 2 weight percent VEC, 2 weight percent TPP and 1 weight percent monophenyl dibutyl phosphate (MDP);

FIGURES 3(A) and 3(B) are graphical representations of data for an oven test illustrated in Fig. 3(A) and a nail penetration test illustrated in Fig. 3B for lithium cells containing flame retardant additives of 2 weight percent VEC, 2 weight percent TPP and 1 weight percent MDP;

FIGURE 4 is a graphical illustration of the relationship of a charge/discharge curve for a half cell with a crystalline natural graphite anode a lithium metal cathode and a 1.2 molar LiPF_6 in 20%EC:70%PC:10%MEC electrolyte without an additive as an electrolyte (EC: Ethylene Carbonate, PC: Propylene Carbonate and MEC: Methyl-ethylene carbonate);

FIGURE 5 is a charge-discharge curve for a half cell with a crystalline natural graphite anode and a lithium metal counter electrode with 1.2 molar LiPF_6 in the same electrolyte as in Fig. 4, the additive being 2 weight percent 4,5-diphenyl-1,3-dioxol-2-

one;

FIGURE 6 is a graphical representation of the area specific impedance, (ASI) change during a 50°C storage of a half cell having a natural graphite anode, a lithium cathode and an electrolyte as